Bull. Natn. Sci. Mus., Ser. A (Zool.), 2 (4), December 22, 1976

The Glass Shrimp, *Pasiphaea japonica* sp. nov. (Caridea, Pasiphaeidae), a Sibling Species of *Pasiphaea sivado*, with Notes on its Biology and Fishery in Toyama Bay, Japan

By

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(Communicated by Yoshinori IMAIZUMI)

Introduction

A pelagic species of the genus *Pasiphaea* occurs in dense concentration in Toyama Bay, the Sea of Japan. It has been exploited for human consumption for more than 100 years. The same species is widely but sparsely distributed along the Pacific coast of central Japan. However, there is no fishing for it in the Pacific Ocean.

Since the description by BALSS (1914) on specimens from off Boshu (Chiba Prefecture), the Japanese *Pasiphaea* have been reported as *P. sivado* (RISSO) (KIKUCHI, 1932, p. 2; YOKOYA, 1933, p. 14; KUBO, 1965, p. 605; AIZAWA, 1974, p. 28). However, I was not convinced that they were really identical with *P. sivado*, which is well known in the Mediterranean Sea (type-locality) and has been found commonly off the Iberian coast and in the Bay of Biscay. In order to compare the Japanese *Pasiphaea* with the European *P. sivado*, I asked the following scientists for the loan of specimens of *P. sivado*: Dr. C. FROGLIA of the Laboratorio di Tecnologia della Pesca, Italy, Dr. L. B. HOLTHUIS of the Rijksmuseum van Natuurlijke Historie, the Netherlands, Dr. J. Y. LE GALL of the Centre Océanologique de Bretagne, France, and Dr. T. WOLFF of the Universitetets Zoologiske Museum, Copenhagen, Denmark. They were kind enough to have sent me the specimens collected from various localities of the Atlantic Ocean and Mediterranean Sea. In his letter to me Dr. HOLTHUIS suggested after his brief examination of the Japanese *Pasiphaea* that they appeared not to be identical with *P. sivado*. The Japanese *Pasiphaea* is very similar to *P. sivado*, but the result of my comparative study led me to the conclusion that it represents a distinct species, rather than a subspecies or an environmentally determined form of *P. sivado*.

This paper presents the results of the comparison of specimens of *P. sivado* from the Mediterranean-Atlantic waters with specimens of *Pasiphaea* from Japanese waters, concluding that the latter represents a new species, *P. japonica*. In addition this paper presents the results of a preliminary survey on *Pasiphaea* made by the R/V *Tansei Maru* between 29 and 31 May 1975 and describes the present status of the unique fishery in Toyama Bay.

I wish to express my appreciation to Drs. C. Froglia, L. B. Holthuis, J. T. Le Gall and T. Wolff who permitted me to examine specimens in their care. Thanks are also due to Mr. S. Doi and Mr. A. Imamura of the Toyama Prefectural Fishery Experiment Station who kindly helped with the sampling of specimens and provided observation on the commercial fishery in Toyama Bay.

Pasiphaea japonica sp. nov.

(Figs. 1 and 2)

Japanese name. Shira-ebi.

Material examined. Toyama Bay, off Iwase, commercial catch by purse seine, 7 Nov. 1973. 8 ovigerous females (58.2–74.5 mm in body length), 8 males (63.8–68.6 mm); off Iwase, commercial catch by purse seine, 0–300 m, 31 Oct. 1974. 21 females (49.5–68.5 mm) including 12 ovigerous females (54.6–68.5 mm), 22 males (47.8–70.3 mm), 5 unsexable juveniles (35.3–44.8 mm).

Suruga Bay, off Kogawa, commercial catch by purse seine for *Sergia* fishing, 0–140 m, 2 Nov. 1970, 4 ovigerous females (62.8–70.4 mm); 35°14.1′N, 139°10.7′E, R/V *Tansei Maru* cruise KT–73–9, Sta. 707–3, 6-ft IKMT. 0–83 m, 22 July 1973. 5 males (52.8–68.2 mm); 35°15.3′N, 139°17.2′E, R/V *Tansei Maru* cruise KT–73–9, Sta. 707–4, 6-ft IKMT, 0–80 m, 23 July 1973. 3 females (56.8–63.0 mm).

Type-series. Holotype, an ovigerous female, body length (bl.), from the tip of the rostrum to the posterior margin of the telson, 65.5 mm, carapace length (cl.), from the tip of the rostrum to the mid-dorsal posterior margin of the carapace, 18.2 mm, from off Iwase, Toyama Bay, 31 Oct. 1974. Allotype, an adult male, 67.5 mm bl., 19.2 mm cl. from the same sample. All other materials examined in the present study are paratypes. The holotype, allotype and 6 paratypes (3 of each sex) from off Iwase have been deposited in the National Science Museum, Tokyo (NSMT–Cr. 5099, 5100 and 5101). Three paratypes of each sex from the same locality have been deposited respectively at the Rijksmuseum van Natuurlijke Historie, Leiden, and the Universitetets Zoologiske Museum, Copenhagen.

Type-locality. Toyama Bay, Japan.

Diagnosis. Carapace not carinate. Abdomen smooth, not carinate; the 6th segment with a large spine posterodorsally. Telson truncate distally with 4 pairs of spinules. The 1st pereiopod extends with only fingers beyond the antennal scale; propodus longer than antennal scale; merus bears 5 to 12 spinules (11 to 24 on a pair of legs). The 2nd pereiopod with 14 to 23 spinules on merus (30 to 43 on a pair of legs).

General description. Rostrum prominent and slender, directed obliquely dorsally; it extends anteriorly about 3/5 between the anterodorsal margin of carapace and the anterior margin of base of rostrum. Carapace compressed but not carinate on dorsal surface; lateral surface of the carapace with suprabranchial carina; anterior margin produced dorsally into a convex, blunt lobe, extending as far anteriorly as the lower orbital angle; this angle continuing ventrally into a weak concave emargination,

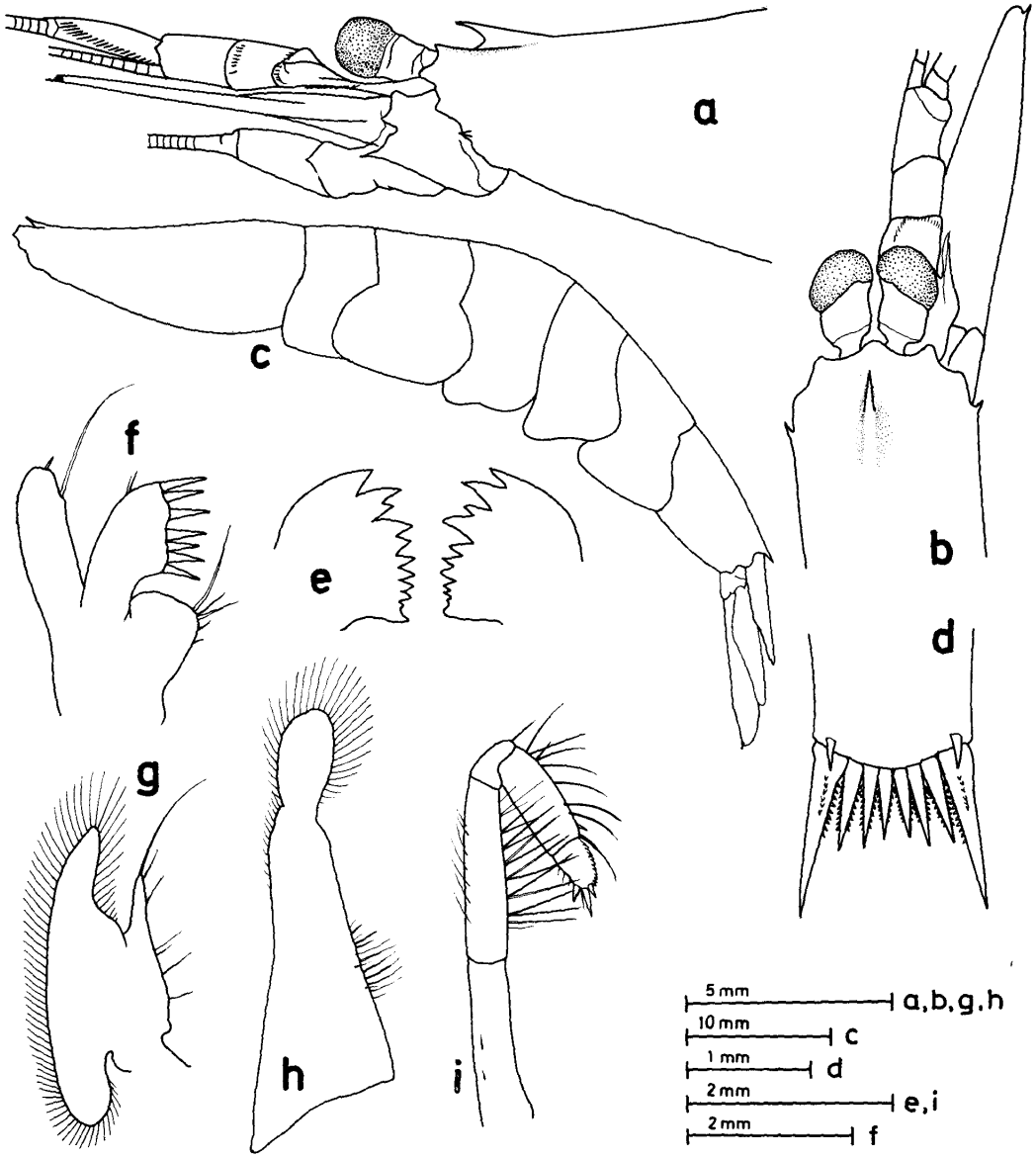

Fig. 1. *Pasiphaea japonica* sp. nov.; a, anterior part of carapace, lateral view; b, anterior part of carapace, dorsal view; c, carapace and abdomen, lateral view; d, tip of telson, dorsal view; e, mandible; f, 1st maxilla; g, 2nd maxilla; h, 1st maxilliped; i, 2nd maxilliped. a–c, from holotype; d–i, from paratype male, 18.7 mm cl.

which in turn passes through a round angle to trend into a concave emargination at level of branchiostegal spine, then into the branchiostegal sinus; branchiostegal spine prominent.

Abdomen smooth; the 1st to 5th segments dorsally rounded and unarmed; the 6th is compressed dorsolaterally, with a large spine posterodorsally; carapace and the

1st to 6th abdominal segments have the following proportional lengths when the body is stretched; 30: 8: 10: 13: 9: 10: 20. Pleura of the 1st and 2nd abdominal segments broadly rounded, the 3rd to 5th produce somewhat anteroventrally; the 6th without dorsolateral carina. Telson 0.7 times as long as the 6th segment; the apex truncated with 4 pairs of spinules; the inner 3 pairs are similar in length; the outermost pair is largest, nearly twice as long as the inner spinules; there is a small spinule at the base of the outer spinule.

Eye well developed; cornea rounded, 1.5 times broader than the length of eye stalk.

The 1st to 3rd segments of antennular peduncle have the proportional lengths, 45: 23: 31. The 1st segment extending with less than 1/3 of the length beyond the eyes; stylocerite narrow in dorsal view and separated from the 1st segment of antennular peduncle at proximal 2/5 of the length, almost reaching the end of the 1st segment proper; two antennular flagellum smooth and slender. Antennal peduncle almost reaching the middle of the 2nd antennular peduncle; basal segment with a strong spine. Antennal scale reaches distally about the end of enlarged segment of the outer antennular flagellum; its outer margin weakly convex and produced into a strong tooth. Mandible with 11-toothed incisor process; palp absent. First maxilla with small truncate proximal endite, toothed distal endite and simple endopod having a stout seta. Second maxilla with simple endopod and large scaphognathite. First maxilliped reduced to large elongated lamella, incompletely articulated distally. Second maxilliped simple, 5-segmented, without epipod or exopod. Third maxilliped with 3-segmented endopod, extending slightly beyond the antennal scale; the exopod well developed.

All pereiopods with well developed exopods, but no epipods. The 1st pereiopod extending with fingers beyond the antennal scale; the fingers slender, cutting edges toothed, tips curved and capable of crossing one another; they are 0.8 times the length of palm; the palm with 2 slender spines, one on distal and the other on middle parts of the ventral inner margin. The 2nd pereiopod slightly longer than the 1st pereiopod; the fingers slender and cutting edges toothed, tips curved; they are 1.3 times as long as the palm. Ischium, merus, carpus and propodus of the 1st and 2nd pereiopods have the following proportional lengths:

	Ischium	Merus	Carpus	Propodus
1st	6	44	8	42
2nd	7	44	6	43

The 3rd pereiopod slender, reaching the cornea. The 4th pereiopod short, reaching the meroischium articulation of the 2nd pereiopod. The 5th pereiopod longer than the 4th pereiopod, reaching the mid-length of merus of the 3rd pereiopod; dactylus laterally broad, and rounded distally. Ischium, merus, carpus, propodus and dactylus of the 3rd to 5th pereiopods have the following proportional lengths:

	Ischium	Merus	Carpus	Propodus	Dactylus
3rd	12	49	5	30	4
4th	14	38	15	21	12
5th	10	37	14	31	8

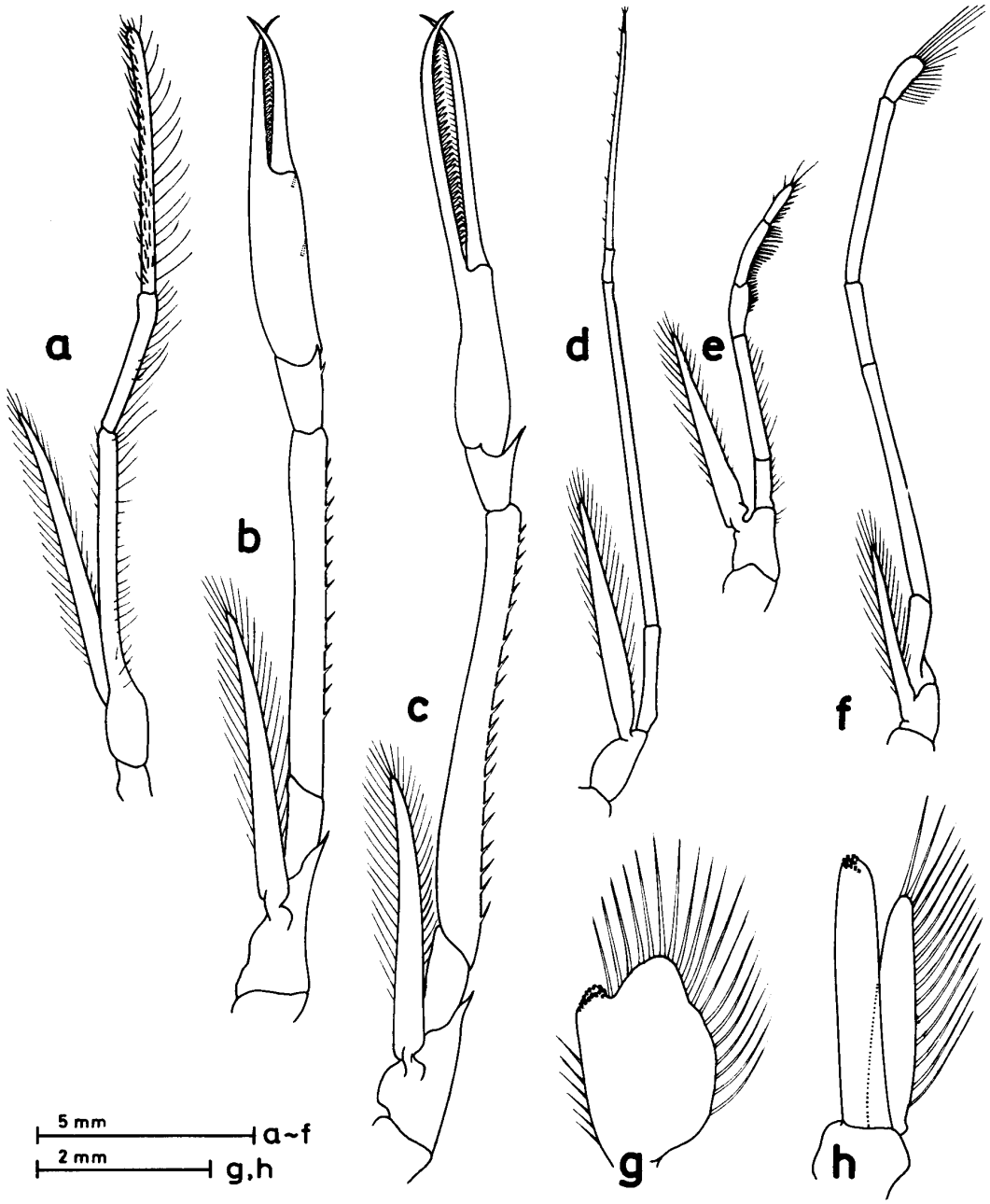

Fig. 2. *Pasiphaea japonica* sp. nov.; a, 3rd maxilliped; b, 1st pereiopod; c, 2nd pereiopod; d, 3rd pereiopod; e, 4th pereiopod; f, 5th pereiopod; g, endopod of 1st pleopod; h, appendix interna and appendix masculina of 2nd pleopod. a–h, from paratype male, 18.7 mm cl.

The 1st pleopod with broad ovate endopod and stout appendix interna. The 2nd to 5th pleopods with slender appendix interna. In the males the 2nd pleopod with a slender appendix masculina. Uropod elongate; the exopod 4.7 times as long as broad, being 1.3 times the length of the endopod.

Colour in life. The body and appendages are mainly transparent; the eyes are black. Large, stellate, red chromatophores irregularly scattering on the body and appendages, differing greatly in concentration with the size of the specimen. Juveniles are almost colourless; the dorsal surface of the abdomen, the posterior half of the carapace and the fingers of the 1st and 2nd pereiopods are faintly red. The ventral surface of the 6th abdominal segment, telson, uropod, basal part of the antennular flagellum and the lower margin of ischium and merus of the 1st to 5th pereiopods are pigmented in large adult specimens. The fingers of the 1st pereiopod and the tip of the exopod of the uropod are particularly reddish; the lower margin of all protopodites of pleopods also appears faintly red.

Systematic Position and Comparison with *Pasiphaea sivado*

Of approximately 35 species in the genus *Pasiphaea, P. japonica* has the characters most similar to *P. sivado*. The specimens of *P. sivado* examined in the present study for the comparison with *P. japonica* were as follows:

Atlantic Ocean (14 females and 20 males)

1) Centre Océanologique de Bretagne. Cineca I, Jan.–Feb. 1971, IK–5 (36°14′N, 9°16′W), 1 male; IK–23 (31°26′N, 10°36′W), 2 females, 1 male; IK–44 (41°08′N, 9°26′W), 2 males; IK–46 (41°06′N, 9°42′W), 6 females, 8 males; IK–47 (41°06′N, 9°51′W), 6 females, 8 males.

Mediterranean Sea (29 females and 22 males)

1) Rijksmuseum van Natuurlijke Historie. No. 5869, Sept. 1934, Catalaanse Kust, Spain, 2 males.

2) Centre Océanologique de Bretagne. Polymede I, May–June 1970, IK–7 (34°36′N, 7°27′E), 1 female.

3) Laboratorio di Tecnologia della Pesca. 18 June 1974, Sta. 25–103 (38°09′N, 12°15′E), 470–600 m bottom-trawl, C. FROGLIA and R. B. MANNING coll., 2 females, 2 males; 17 June 1970, off Sicily, Gulf of Patti, 500 m trawl, G. BOMBAC coll., 9 females, 7 males.

4) Universitetets Zoologiske Museum. 19 Jan. 1909, *Thor* Sta. 28 (40°53′N, 13°43′E), 65 m.w., 17 females; 20 Jan. 1909, *Thor* Sta. 27 (40°58′N, 13°49′E), 65 m.w., 11 males.

Body length, carapace length, length of antennal scale and length of merus and propodus of the 1st pereiopod in the samples of *P. japonica* and *P. sivado* are compared in Tables 1 and 2. The length of the antennal scale measured from the tip of tooth to the posterior margin; that of the merus and propodus of the 1st pereiopod is entire length of the upper margin. With regard to *P. sivado*, the Atlantic population appears

Table 1. Body length, carapace length, length of antennal scale, and lengths of merus and propodus of the 1st pereiopod in samples of *Pasiphaea japonica* and *P. sivado* (females).

Species	*P. japonica*	*P. sivado*	*P. sivado*
Locality	Toyama Bay	Mediterranean	Atlantic
No. of specimens	26	29	14
Body (mm)			
Range	49.5–74.5	48.5–71.0	48.0–59.4
$\bar{x}$	60.91	57.93	52.85
s	5.57	4.84	3.82
Carapace (mm)			
Range	14.2–22.0	14.5–21.5	14.0–18.7
$\bar{x}$	17.12	17.59	16.10
s	1.60	1.61	1.33
Antennal scale (mm)			
Range	6.5–9.4	6.0–8.4	5.7–7.6
$\bar{x}$	7.95	7.21	6.67
s	0.77	0.60	0.60
Merus of 1st pereiopod (mm)			
Range	5.4–8.3	6.0–8.5	5.4–7.6
$\bar{x}$	7.05	7.29	6.65
s	0.77	0.63	0.67
Propodus of 1st pereiopod (mm)			
Range	6.0–8.7	6.4–8.7	6.2–8.0
$\bar{x}$	7.43	7.89	7.17
s	0.74	0.55	0.56
Antennal scale/Merus of 1st pereiopod			
Range	1.04–1.22	0.93–1.03	0.98–1.06
$\bar{x}$	1.130	0.989	1.007
s	0.046	0.032	0.031
Antennal scale/Propodus of 1st pereiopod			
Range	0.96–1.19	0.83–0.97	0.88–1.00
$\bar{x}$	1.066	0.916	0.932
s	0.051	0.037	0.034

slightly different from the Mediterranean population, and they were treated separately. There was no structural difference between *P. japonica* from Toyama Bay and that from Suruga Bay.

Assignment of the sibling populations *P. japonica* and *P. sivado* to separate species is based on three lines of evidence: 1) significant differences in the number of spinules on the meri of the 1st and 2nd pereiopods (Tables 3 and 4, Figs. 3 and 4); 2) significant differences in ratio between the length of antennal scale and the length of propodus of the 1st pereiopod (Fig. 5); 3) apparent restriction of each population in temperate zones of the Mediterranean Sea—northeast Atlantic Ocean and the north-

Table 2. Body length, carapace length, length of antennal scale, and lengths of merus and propodus of the 1st pereiopod in samples of *Pasiphaea japonica* and *P. sivado* (males).

Species	*P. japonica*	*P. sivado*	*P. sivado*
Locality	Toyama Bay	Mediterranean	Atlantic
No. of specimens	23	22	20
Body (mm)			
Range	47.8–70.3	47.5–67.2	45.5–66.1
$\bar{x}$	62.77	57.56	58.18
s	6.63	6.17	5.57
Carapace (mm)			
Range	14.0–21.2	14.0–21.7	13.5–20.0
$\bar{x}$	18.32	17.81	17.79
s	2.00	2.04	1.80
Antennal scale (mm)			
Range	6.0–10.0	5.7–8.9	5.9–8.7
$\bar{x}$	8.59	7.36	7.62
s	1.09	0.89	0.84
Merus of 1st pereiopod (mm)			
Range	5.3–8.9	5.7–9.5	6.2–8.5
$\bar{x}$	7.74	7.51	7.53
s	1.01	0.99	0.78
Propodus of 1st pereiopod (mm)			
Range	5.9–9.4	6.5–9.7	6.6–8.9
$\bar{x}$	8.02	8.14	8.00
s	0.98	0.84	0.68
Antennal scale/Merus of 1st pereiopod			
Range	1.01–1.23	0.94–1.02	0.95–1.05
$\bar{x}$	1.111	0.980	1.013
s	0.047	0.026	0.026
Antennal scale/Propodus of 1st pereiopod			
Range	0.98–1.14	0.85–0.96	0.86–1.01
$\bar{x}$	1.071	0.902	0.952
s	0.036	0.031	0.039

western Pacific Ocean.

A relatively high degree of variability in the number of spinules on the meri of the 1st and 2nd pereiopods has been reported for *P. sivado* (STEPHENSEN, 1923). In the present study the females and males were treated together and for each sexually matured specimen the numbers of spinules were tallied from both left and right members of the 1st and 2nd pereiopods. The difference in the number of spinules between the right and left legs varied from 0 to 3 with an exceptional 4 and 8; in the 1st pereiopod in 28% there was no difference, in 51% a difference of 1, in 15% a difference of 2; in the 2nd pereiopod in 32% no difference, in 39% a difference of 1,

Table 3. Total number of spinules on the merus of the 1st pereiopod in samples of *Pasiphaea japonica* and *P. sivado* (females and males combined), with comparison of differences between mean number (Student's *t*-test) and coefficient of difference (C.D.).

Species	Location	No.	Range	$\bar{x}$	s^2	s	*t*	p	C.D.
P. japonica	Toyama Bay	49	11–24	16.592	8.538	2.922			
P. sivado	Mediterranean	48	6–15	11.000	4.596	2.144			
P. sivado	Atlantic	33	3–11	8.061	5.184	2.277			
P. japonica: Medit. *P. sivado*		97			6.588	2.567	10.73	<0.001	1.10*
P. japonica: Atl. *P. sivado*		82			7.197	2.683	14.12	<0.001	1.64**
Medit. *P. sivado*: Atl. *P. sivado*		81			4.834	2.199	5.91	<0.001	0.66***

* Joint non-overlap, 86%
** " 95%
*** " 73%

Table 4. Total number of spinules on the merus of the 2nd pereiopod in samples of *Pasiphaea japonica* and *P. sivado* (females and males combined), with comparison of differences between mean number (Student's *t*-test) and coefficient of difference (C.D.).

Species	Location	No.	Range	$\bar{x}$	s^2	s	*t*	p	C.D.
P. japonica	Toyama Bay	49	30–43	34.102	10.594	3.255			
P. sivado	Mediterranean	51	17–32	24.490	12.135	3.484			
P. sivado	Atlantic	32	11–30	19.438	14.770	3.843			
P. japonica: Medit. *P. sivado*		100			11.380	3.373	14.25	<0.001	1.43*
P. japonica: Atl. *P. sivado*		81			12.232	3.498	18.44	<0.001	2.07**
Medit. *P. sivado*: Atl. *P. sivado*		83			13.144	3.625	6.18	<0.001	0.69***

* Joint non-overlap, 92%
** " 99%
*** " 76%

in 21% a difference of 2.

The mean number of spinules on the meri showed a pronounced geographical trend. The highest value was obtained from *P. japonica* and the lowest from the Atlantic population of *P. sivado*. The Mediterranean *P. sivado* yielded a mean number of spinules roughly midway between the above two. There seems to be gross indication of clinal variation from the Atlantic population of *P. sivado* to *P. japonica*. The coefficient of difference value (C. D., MAYR *et al.*, 1953, p. 146) in the number of spinules on the merus of the 1st pereiopod between *P. japonica* and the Mediterranean *P. sivado* was only 1.10, whilst it was 1.64 between *P. japonica* and the Atlantic *P. sivado*. However, at present the detailed structure of a *P. sivado*-like species from the Indian Ocean is not known. The difference in the antennal scale/propodus of the 1st pereiopod length ratio between *P. japonica* and *P. sivado* proved to be highly significant. The C.D. value was more than 1.58 (joint non-overlap,

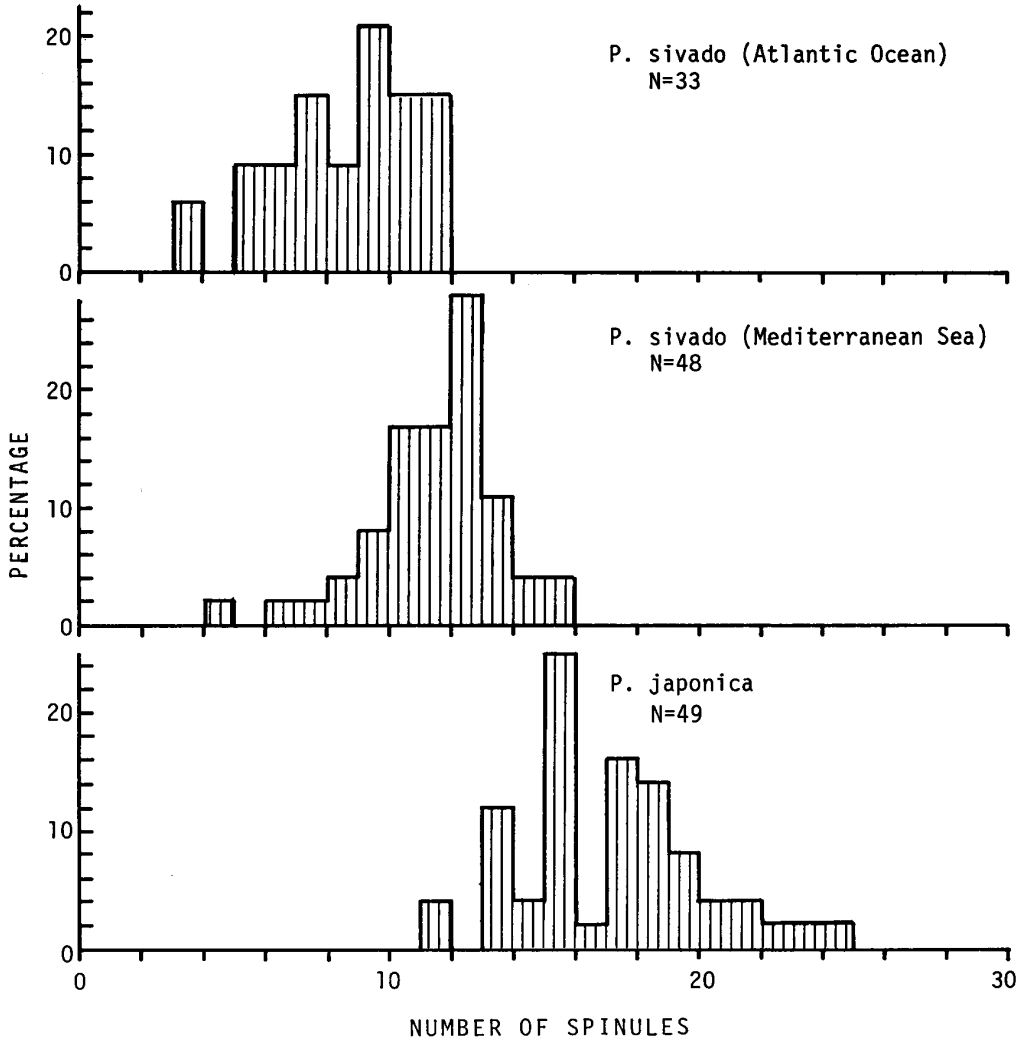

Fig. 3. Number of spinules on the merus of the 1st pereiopod in samples of *Pasiphaea japonica* and *P. sivado*.

>94%). And, different from the case of the meral spinulation, the mean value of the ratio was greatest in *P. japonica* and smallest in the Mediterranean *P. sivado*.

In *P. sivado* the 1st pereiopod extends with fingers and at least 1/4 of palm beyond the antennal scale, but in *P. japonica* it extends beyond the antennal scale with fingers only. This character can be used for the separation of two species without magnification.

The body length and carapace length in *P. japonica* and *P. sivado* have the following relationship:

	Females	Males
P. japonica	Y=3.14X+5.79	Y=3.00X+8.38
P. sivado (Mediterranean Sea)	Y=2.84X+8.06	Y=2.89X+5.82
P. sivado (Atlantic Ocean)	Y=3.16X+2.58	Y=2.95X+6.20

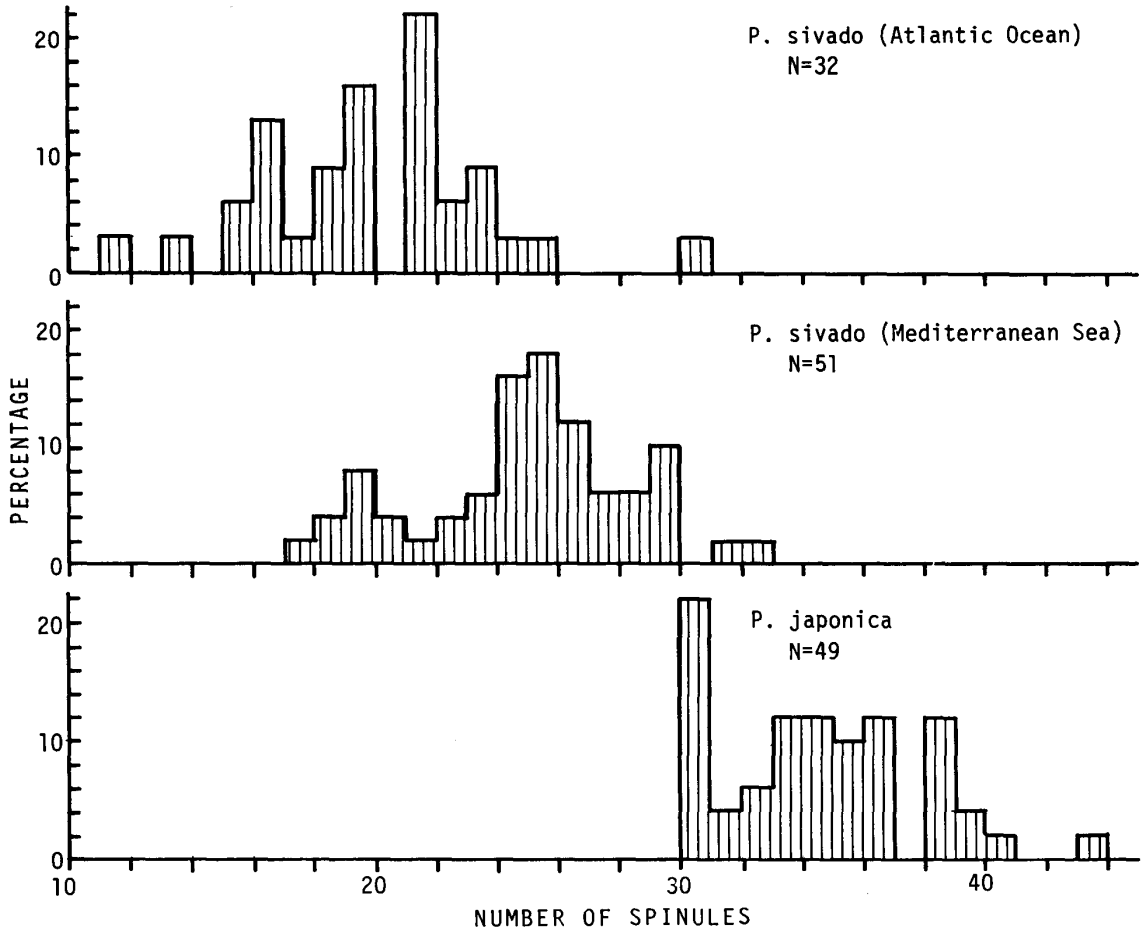

Fig. 4. Number of spinules on the merus of the 2nd pereiopod in samples of *Pasiphaea japonica* and *P. sivado*.

where Y is body length (mm) and X is carapace length (mm).

Biological Characters of *Pasiphaea japonica*

The smallest ovigerous female examined in the material available had 54.6 mm bl. A male with 37.0 mm bl. had an extremely small appendix masculina. Usually, however, the sex of specimens with 40–45 mm or less was not discernible. As pointed out previously (Doi, 1975), the difference in width of the coxa of pleopods is a clear sexual distinction in larger specimens; the coxa of the 2nd pleopod of males is nearly as long as wide in lateral view, whilst it is much longer than wide in the females. This character can be easily used for sexing without magnification. The size at maturity is about 50–55 mm bl. All males above this size bear a well developed appendix masculina and all females above this size possess a clearly visible, developing ovary.

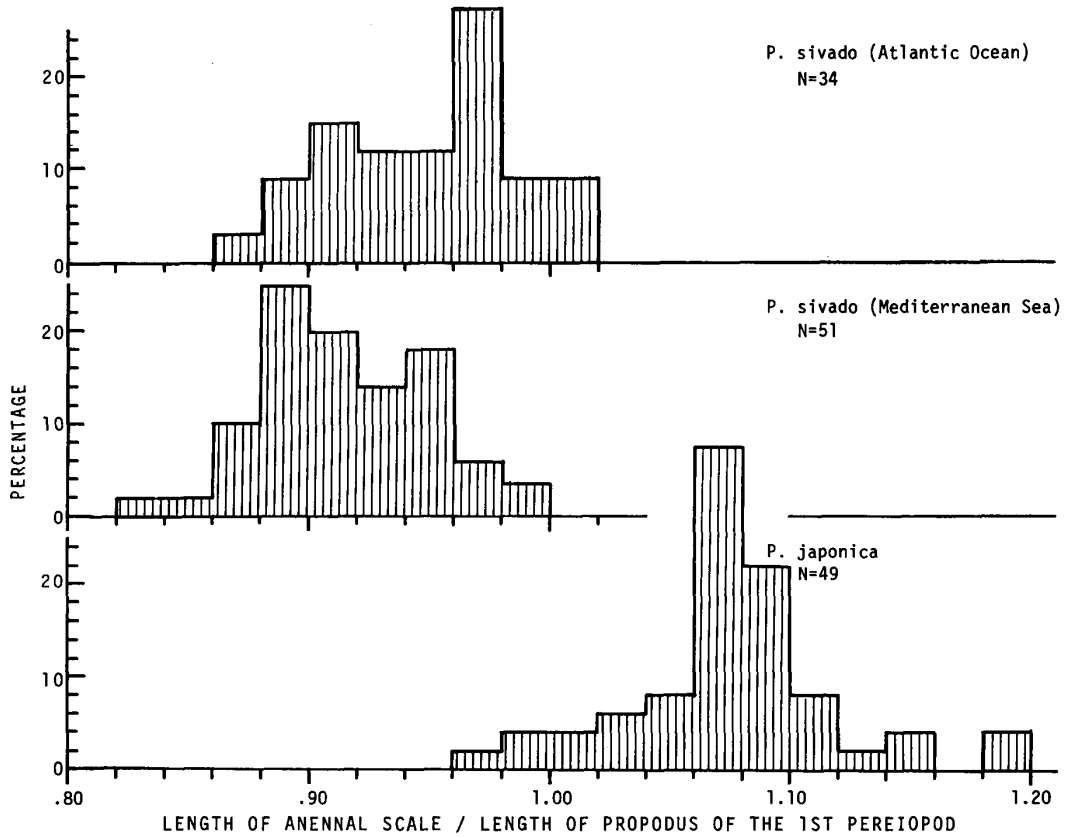

Fig. 5. Ratio between the length of antennal scale and the length of propodus of the 1st pereiopod in samples of *Pasiphaea japonica* and *P. sivado*.

The number of eggs attached beneath the abdomen of the species shows considerable variation, ranging from 53 to 172 in 16 specimens with between 14.8 and 22.0 mm cl. The number increases with size of the females (Fig. 6). DOI (1975) reported that a specimen had 281 riped eggs. Final dimensions of the embryos are about 1.8×1.3 mm.

Figure 7 shows the carapace length histogram of 275 individuals of *P. japonica* collected in the fishing ground off Mizuhashi (36°46.3′N, 137°17.7′E) on 30 May 1975 during the *Tansei Maru* survey. The sampling was made by an oblique towing with the 6-ft IKMT, 2 mm in mesh openings, between the surface and the seafloor (210 m). Graphical analysis of frequency distributions (CASSIE, 1954) indicates that there are apparently 5 modes in the histogram, suggesting the occurrence of 5 broods of different generation. Apparently, the mesh size of the trawl was too large to collect the larvae of the smallest size group. In this connection the 1st zoeal stage larva that hatched out from egg of *P. japonica* is approximately 1.7 mm cl. (5.6–6.1 mm bl.; 1.94 mg wet weight per individual). On the other hand, the females with developed ovaries were taken in Toyama Bay through most of the year in 1974. However, monthly observation of specimens from commercial catch indicated that the occurrence

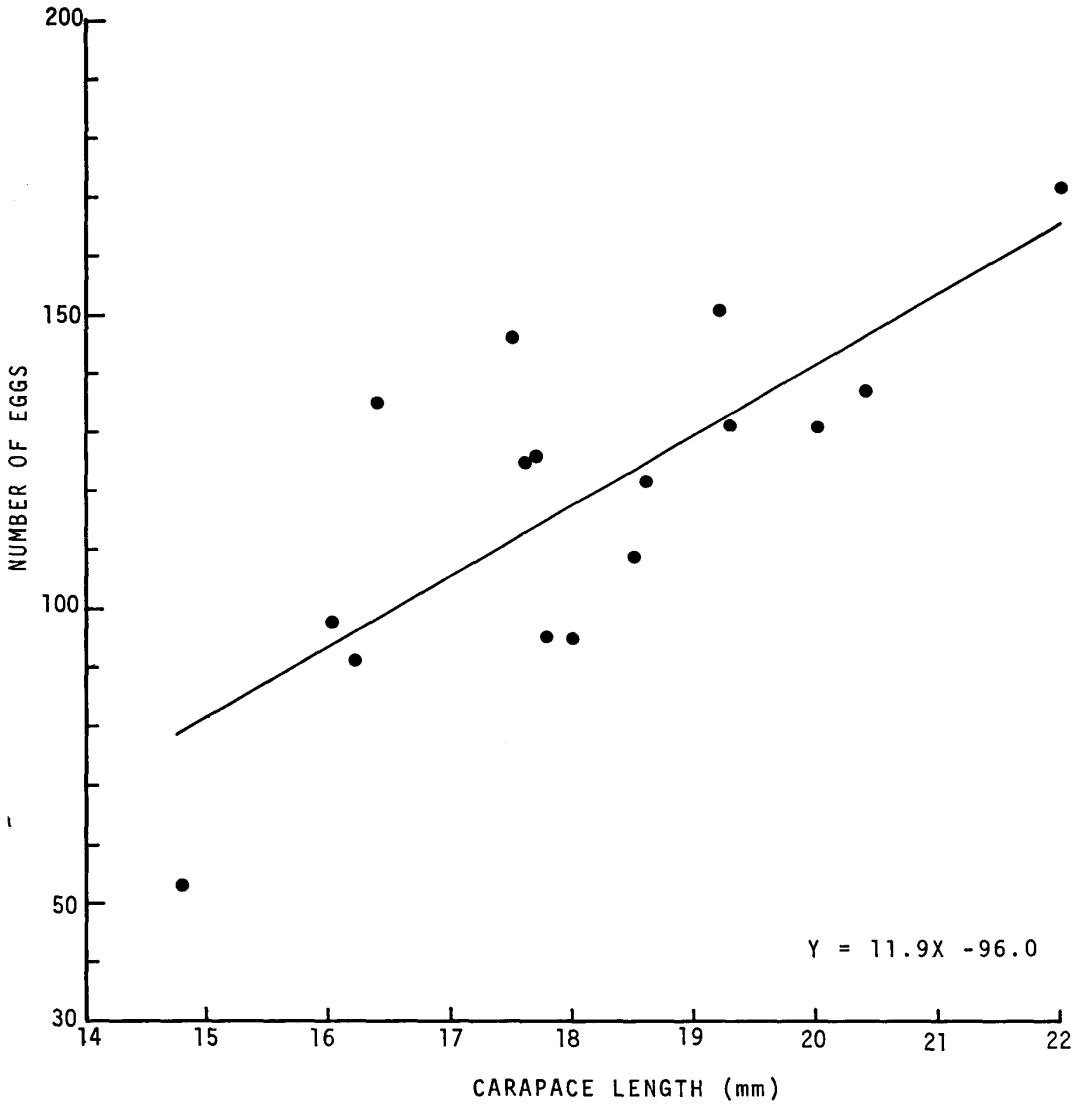

Fig. 6. *Pasiphaea japonica*. Number of eggs and carapace length of ovigerous females.

of females with riped eggs fell from the end of May to early June and again from the end of September to early October (Doi, personal communication). This fact indicates that *P. japonica* produces eggs twice a year, and that the hatching takes place in May–June and in September–October. A second brood would be entruded soon after the hatching of the first. Assuming that the animals in the smallest size group in Fig. 7 hatched in May and that the second smallest (average 6.0 mm cl.) hatched in October of the previous year, *P. japonica* matures sexually at an age of 17 months and releases first brood at an age of 2.0 years. As the species attain nearly 80 mm bl. at most (Doi, 1975), its life-span is estimated to be mostly 2.5 years but in a few cases it may live for 3 years and spawn three times. The number of eggs produced by

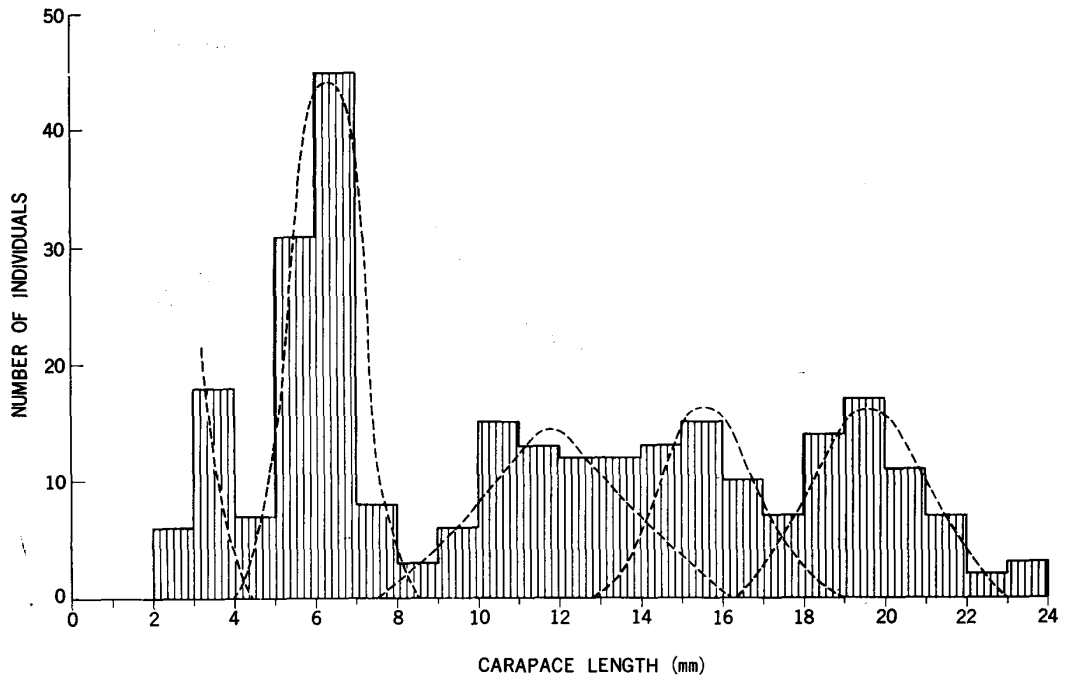

Fig. 7. *Pasiphaea japonica.* Frequency distribution of carapace length of 275 specimens collected off Mizuhashi, Toyama Bay, on 30 May 1975.

a female during its life would therefore be about 220 (two spawnings) to 410 (three spawnings). It grows to 0.027 mm cl. or 0.096 mm bl. per day during the first 17 months. As the wet weight of the female specimen of 15.5 mm cl. is 907.9 mg [$W=0.0631\ L^{3.498}$, where W is wet weight and L is carapace length of female (Doi, 1975)], average growth rate in the 17 months is estimated to be 0.92 per day.

Distribution

Toyama Bay is located on Honshu, between latitudes 36°45′N and 37°00′N and longitudes 137°00′E and 137°26′E. Like Suruga Bay of the Pacific coast, the bottom slope of Toyama Bay is very steep. The continental shelf is so narrow and most depths in the bay are greater than 200 m. Many rivers flow into the bay, and these river-beds connect almost directly to narrow, V-shaped canyons in the sea, which extend towards the deep basin. The greatest depth at the mouth of the bay is about 1,300 m (Fig. 8).

The *Tansei Maru* survey in Toyama Bay, May 1975, revealed that *P. japonica* is found on the steep slope at the edge of canyons near the seashore between the mouths of the Sho River and Hayatsuki River. The distribution extends toward offshore where the bottom ranges 500–600 m, but no species was collected from offshore beyond those depths. During the day these shrimps were concentrated close to the sea-floor, probably a few meters (not more than 20 m) above the muddy bottom.

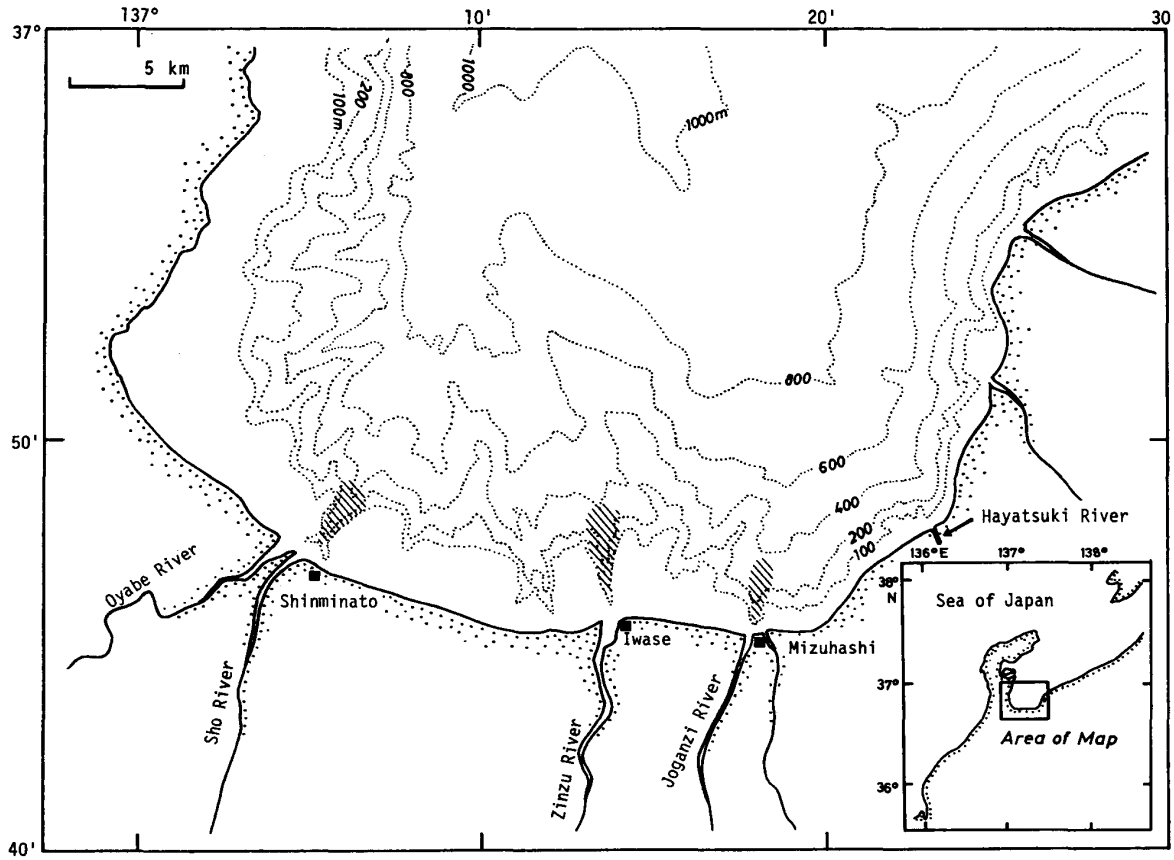

Fig. 8. Fishing grounds of *Pasiphaea japonica* in Toyama Bay (hatched areas). Inserted map shows location of Toyama Bay.

In the Sea of Japan *P. japonica* appears to occur widely not only in Toyama Bay but also along other coastlines. The species is often found in the stomachs of *Pneumatophorus japonicus* (HOUTTUYN) and *Pleurogrammus azonus* JORDAN et METZ, both commercially important fishes caught off Niigata Prefecture, east of Toyama Bay (NISHIMURA, 1959; HORIE, personal communication). In addition to Toyama Bay and Suruga Bay, I have found *P. japonica* in numerous hauls in Sagami Bay and Enshu Nada (Sea) in the Pacific. It is most probable that all records that have been reported from Japan as *P. sivado* by previous authors are those of *P. japonica*.

Pasiphaea sivado has never been adequately described and illustrated until ZARIQUIEY ALVAREZ (1957). This caused much confusion in the taxonomy of the species having the characters similar to *P. sivado*. Previous descriptions of *P. sivado* from the Red Sea, the Gulf of Oman, the Arabian Sea, and the Andaman Sea (WOOD-MASON and ALCOCK, 1893, p. 161; ALCOCK, 1901, p. 59; BALSS, 1915, p. 17; CALMAN, 1939, p. 185) are inadequate, and their records of the occurrence need re-examination. The smallest ovigerous female of *P. sivado* from the Mediterranean Sea—northeastern Atlantic Ocean is 48 mm bl. (STEPHENSEN, 1923). However, CALMAN's *P. sivado* from

the Gulf of Oman and the northern Arabian Sea are ovigerous females of only 30 to 36 mm bl., and the numbers of spinules on the meri of their 1st and 2nd pereiopods are 13–15 and 18+ respectively (probably combined number of the pair of legs). BALSS's specimens from the Red Sea are also about 35 mm, and appear to be identical with CALMAN's. The males and ovigerous female from the Andaman Sea (WOOD-MASON and ALCOCK, 1893; ALCOCK, 1901) are 48 mm bl.

Fishery in Toyama Bay

Fishing grounds of *P. japonica* in Toyama Bay are off Shinminato (mouth of Sho River), off Iwase (mouth of Zintsu River) and off Mizuhashi (mouth of Joganzi River) (Fig. 8). Each fishing ground is near the mouth of the river and is very localized. Swarms are usually found on the steep slope where the depth ranges from 150 to 400 m. Presumably the shrimp ascends from deep offshore part to shallow coastal part at night and descends along the edge of the canyon by day. Under this condition the shrimp would particularly concentrate by day at or near the sea-floor between slopes of narrow canyon where the depth is slightly shallower than their usual daytime residence depth.

The shallow water of Toyama Bay is influenced by the warm Tsushima Current (a branch of the Kuroshio that moves along the coast of Honshu in the Sea of Japan). The temperature at 100 m layer generally fluctuates from 9°C in April to 16°C in November, while it is from 5°C in April to 11°C in January at 200 m layer. The depths greater than 300 m are below 3°C throughout the year. The salinity between 100 and 200 m layers varies between 33.4 and 34.5‰.

The fishing is carried out by boat seine. It is licenced by law, and at present the commercial fishing operations are conducted by three fishing unions located in the towns of Shinminato, Iwase and Mizuhashi. The fishing commences on 1 April and is closed on 30 November by existing regulation. During the fishing season a total of 25–30 boats are engaged in the fishing. General construction of the boat seine is as follows: the wing, which consists of a graded series of 4–5 different mesh sizes from 115 to 32 mm (two legs) is about 70 m long and 80 m wide; the bag is 30 m long and is composed of graded nets ranging 30 to 15 mm in mesh size. A warp of about 400 m long is connected to each wing of the net. The net is hauled upwards from the bottom along the slope by a wooden boat of about 5 gross tons. During the net haul the foot rope is maintained 5–10 m above the seafloor. When the net is hauled precisely, the catch is almost entirely composed of the *Pasiphaea*. An average catch per haul is 25–45 kg (about 16,000–30,000 inds.) but occasionally 400–1,000 kg are obtained at once. The number of fishing days per year is 60–85. The total annual catches (wet weight) in Toyama Bay during the past 20 years are shown in Fig. 9. The catches fluctuated between 200 and 500 metric tons recently. Generally about 50% of the catch is landed by Iwase and 40% by Shinminato. Monthly catches vary considerably, but usually the best month is April, May or August.

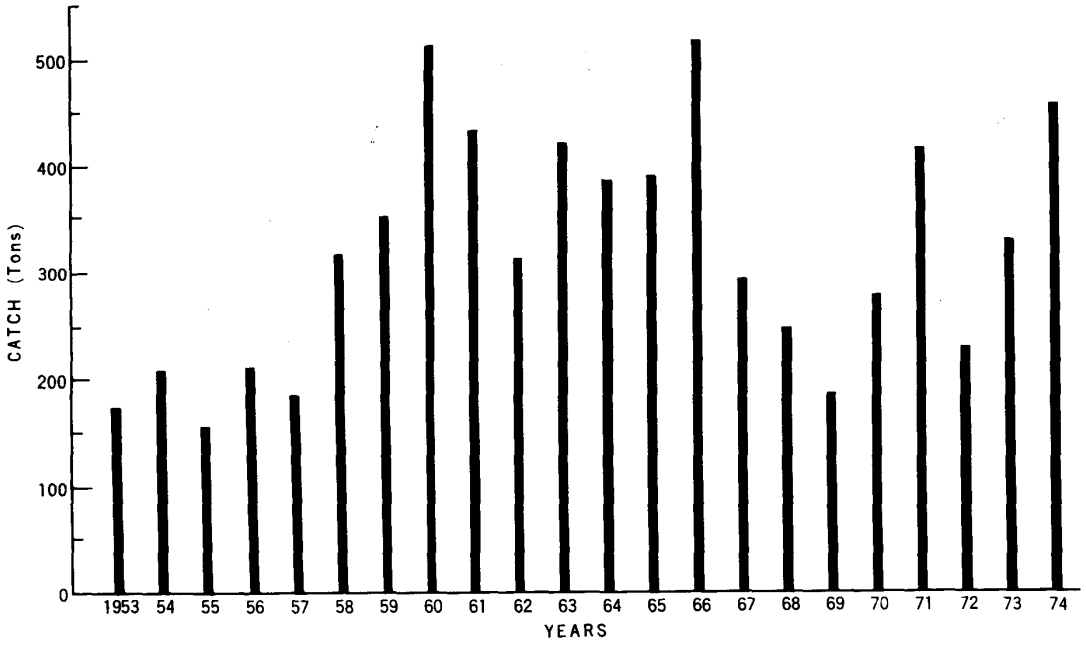

Fig. 9. Fluctuation in annual catches of *Pasiphaea japonica* in Toyama Bay.

Annual value of the landed shrimp at Iwase was about 41,000,000 Yen for 109 tons in 1973.

Probably Toyama Bay is the only place in the world where the shrimp of the genus *Pasiphaea* is exploited for human consumption. The fauna of the Sea of Japan is characterized by small number of meso- and bathypelagic species and by a mass development of a few species. Owing to the shallowness of the straits connecting it with the ocean, many common animals in the North Pacific are prevented to enter the sea. A few organisms could therefore be enjoying a corresponding population boom in the Sea of Japan. Good examples are *P. japonica*, as well as the luminous squid *Watasenia scintillans* (BARRY) and the anglemouth fish *Maurolicus japonicus* ISHIKAWA. Although they are a minor mesopelagic group in the Pacific, their tremendous aggregations are often reported in the southern coastal area of the Sea of Japan. Their role in the food web and ecosystem in the Sea of Japan must be greater than that in the Pacific Ocean.

Summary

Pasiphaea japonica sp. nov., which is closely related to the Mediterranean-Atlantic species *P. sivado* and has hitherto been identified with the latter species by previous authors, is described. Morphological comparison with *P. sivado* is made. The life-span of the new species is 2.5–3.0 years. It matures sexually at an age of about 1.5 years and produces eggs usually twice but in a few cases three times during its life. The species is distributed in the coastal waters of Japan, and exploited for

human consumption in Toyama Bay, the Sea of Japan. The catch amounts to 200–500 tons a year.

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